Claims

1. A tubular solid oxide fuel cell assembly comprising:
   (a) a tubular, substantially metallic porous support layer; and
   (b) a tubular, functional layer assembly in concentric adjacent contact with the support layer, having a wall thickness less than or equal to 80 μm and comprising in concentric arrangement: a ceramic or cermet inner electrode layer, a ceramic middle electrolyte layer, and a ceramic or cermet outer electrode layer;

   wherein the support layer has sufficient mechanical strength to support the functional layer assembly, and sufficient porosity to allow the flow of a reactant therethrough.

2. The fuel cell assembly of claim 1 wherein the functional layer assembly wall thickness is less than or equal to 65 μm and diameter is less than or equal to 5 mm.

3. The fuel cell assembly of claim 2 wherein the diameter of the functional layer assembly is less than or equal to 2 mm.

4. The fuel cell assembly of claim 2 wherein the wall thickness of the functional layer assembly is less than or equal to 20 μm.

5. The fuel cell assembly of claim 1 wherein the electrolyte composition substantially comprises a material selected from the group of yittria-stabilized zirconia and Gd_2O_3 – doped CeO_2.

6. The fuel cell assembly of claim 5 wherein the electrolyte composition comprises yittria-stabilized zirconia and has a thickness less than or equal to 5 μm.

7. The fuel cell assembly of claim 5 wherein the electrolyte composition comprises Gd_2O_3 – doped CeO_2 and has a thickness of less than or equal to 15 μm.

8. The fuel cell assembly of claim 5 wherein the electrolyte composition includes at least one sintering additive selected from the group of: cobalt oxide; cobalt

oxide and iron oxide; cobalt oxide and copper oxide; cobalt oxide, copper oxide and iron oxide; cobalt and iron; cobalt and copper; cobalt, copper and iron; bismuth oxide; bismuth based (Bi-Sr-Ca-Cu-O) ceramic superconductors; and Bi-Sr-Ca-Cu-O.

9. The fuel cell assembly of claim 1 wherein the support layer has a thickness of between 20 and 500 μm.

10. The fuel cell assembly of claim 9 wherein the support layer composition substantially consists of a material selected from the group consisting of: stainless steel, ferritic steel, silver nickel alloy and super-alloy, copper, nickel, copper-alloys, nickel-alloys, copper-nickel mixture, copper/ceramic cermet, copper-alloy/ceramic cermet, copper-nickel/ceramic cermet, copper-silver, and, copper-nickel-silver.

11. The fuel cell assembly of claim 1 wherein the inner electrode layer is an anode and has a thickness of between 1 and 20 μm.

12. The fuel cell assembly of claim 1 wherein the outer electrode layer is a cathode and has a thickness of between 1 and 30 μm.

13. A fuel cell stack comprising
    (a) a plurality of the fuel cell assemblies of claim 1; and
    (b) a continuous solid phase porous matrix embedding the fuel cells and having a porosity sufficient to flow a reactant therethrough and to the outer surface of the embedded fuel cells.

14. The fuel cell assembly of claim 1 wherein the support layer and functional layer assembly are in mechanical and electrical contact, and the support layer has sufficient electrical conductivity to collect current during fuel cell operation.

15. The fuel cell assembly of claim 1 wherein the support layer is inside the functional layer assembly and is in contact with the inner electrode layer.

16. The fuel cell assembly of claim 1 wherein the functional layer assembly is inside the support layer and the support layer is in contact with the outer electrode layer.

17. A method of manufacturing a tubular solid oxide fuel cell assembly comprising:
(a) coating a tubular substantially metallic support layer with a ceramic or cermet inner electrode layer,
(b) coating the inner electrode layer with a ceramic electrolyte layer;
(c) coating the electrolyte layer with a ceramic or cermet outer electrode layer, then
(d) sintering the layers to produce a hollow tubular metal-supported fuel cell;
the electrode and electrolyte layers having a collective wall thickness of 80 μm or less, the support layer having sufficient mechanical strength to support the electrode and electrolyte layers and sufficient porosity to flow a reactant therethrough.

18. The method of claim 17 wherein the inner electrode layer is coated on the support layer by one in the group of electrophoretic deposition, dip-coating, and spraying.

19. The method of claim 17 wherein the electrolyte layer is coated on the inner electrode layer by one in the group of electrophoretic deposition, dip-coating, sol-gel coating, and spraying.

20. The method of claim 17 wherein the metal support layer includes combustible additives, and wherein in step (d), the combustible additives are combusted thereby producing a porous metal support layer.

21. The method of claim 17 wherein at least one of the electrode layers includes combustible additives, and wherein in step (d), the combustible additives are combusted thereby producing a electrode layer with increased porosity.

22. The method of claim 17 further comprising between steps (a) and (b), drying and sintering the inner electrode layer and support layers before the electrolyte and outer electrode layers are applied.

23. The method of claim 17 further comprising between steps (b) and (c), drying and sintering the inner electrode layer and electrolyte layers before the outer electrode layer is applied.

24. A method of manufacturing a tubular solid oxide fuel cell comprising
    (a) coating a combustible non-conductive substrate member with a conductive substrate layer;
    (b) coating the substrate layer with an inner electrode layer by electrophoretic deposition;
    (c) coating the inner electrode layer with an electrolyte layer;
    (d) coating the electrolyte layer with an outer electrode layer, then
    (e) drying and sintering the layers such that the substrate member combusts, thereby producing a hollow tubular fuel cell.

25. The method of claim 24 further comprising between steps (c) and (d), drying and sintering the coated substrate such that substrate member combusts before the outer electrode layer is applied.

26. The method of claim 24 wherein the substrate member composition comprises a material selected from the group of wood, polymer, paper, jute fibers and polymer fibers/filaments.

27. The method of claim 24 wherein the conductive substrate layer composition comprises a material is selected from the group of metal, carbon, graphite and conductive polymers.

28. The method of claim 27 wherein the conductive substrate layer substantially comprises a non-combustible metal and a combustible additive, and wherein sufficient conductive substrate layer material is applied to provide the conductive substrate layer with sufficient mechanical strength to support the electrode and electrolyte layers during fuel cell operation, and wherein during sintering, the combustible additive combusts thereby producing a porous metal support layer.

29. The method of clam 28 wherein the metal is selected from the group of stainless steel, ferritic steel, super-alloy, Cu, Ni, Cu-alloys, Ni-alloys, Cu-Ni

mixture, Cu (or Cu-alloy)/ceramic cermet, Cu-Ni/ceramic cermet, Cu-Ag, and Cu-Ni-Ag.

30. The method of claim 24 wherein the conductive substrate layer is combustible, and combusts during sintering.

31. The method of claim 30 wherein between steps (a) and (b), the conductive substrate layer is coated with a substantially metallic support layer by electrophoretic deposition, the metallic support layer having sufficient mechanical strength to support the electrode and electrolyte layers during fuel cell operation, and sufficient porosity to enable the flow of a reactant therethrough.

32. The method of claim 30 further comprising coating the outside electrode layer with a substantially metallic support layer to produce a porous, substantially metallic support layer having sufficient mechanical strength to support the electrode and electrolyte layers during fuel cell operation, and sufficient porosity to enable the flow of a reactant therethrough.

33. The method of claim 30 wherein sufficient electrode material is applied to produce an electrode-supported fuel cell.

34. The method of claims 31 or 32 wherein the electrode and electrode layers collectively have a thickness of less than or equal to 80 μm and the support layer has a thickness between 20 and 500 μm.

35. The method of claim 24 wherein the substrate layer material is substantially metallic, and between steps (a) and (b), the coated substrate member is dried and sintered such that the substrate member combusts, then the remaining metallic substrate layer is shaped.

36. The method of claim 24 wherein in step (a), the substrate is coated with a polymer binder solution before the conductive substrate layer is applied, to enhance the smoothness and reduce the porosity of the substrate surface.